THE ROBUSTNESS OF THE DOMESTIC HOUSE
PART 2 : WIND SUCTION TESTS ON GABLE WALLS

G.J. EDGELL, Civil Engineer
British Ceramic Research Association Ltd., Stoke-on-Trent, England

R.C. DE VEKEY, Head of Masonry Section, Structural Integrity Division
Building Research Establishment, Watford, England

ABSTRACT

Wind blowing parallel to the gable walls of domestic houses causes local suction pressures and those have led in some cases to a failure of the masonry. Failures are often localised and part of the wall near to the verges is sucked out. In most cases a number of factors have contributed to the failure, these may include inadequate connections between the wall and the roof or ceiling and corrosion of the wall ties. However, it was considered necessary to evaluate the degree of safety in this respect associated with modern housing construction. The common use of trussed rafters now leads to a situation where none of the roof self weight passes into the gable wall and the restraint is provided by light straps at verge and ceiling. The paper describes suction tests on the top part of the gable wall of a semi-detached house constructed in the laboratory. The wall is tested to destruction and reconstructed for further testing. The results are considered and the improvement due to a revision of the strapping detail is demonstrated.

1. INTRODUCTION

The majority of the domestic housing which is built in the U.K. is designed using empirical rules in Schedule 7 to The Building Regulations[1]. These rules are based on experience with the use of traditional materials and construction methods and in recent years there have been trends that lead to changes in the ways that strength and stability of the structure are ensured. Consequently it was considered appropriate to review the empirical rules.

A full scale semi-detached domestic house has been constructed in the laboratory and the results of compressive loading tests on the walls have been reported elsewhere[2,3]. The plan and elevation of the house are shown in Figure 1. The gable wall contains no window openings.

The use of prefabricated trussed rafters for the roofs of houses means that the weight of the roof and any superimposed load eg snow is transmitted into the front and rear walls. In rafter and purlin roof structures this load would be transmitted into the gable and party walls. As the top of the gable wall in a house with a trussed rafter roof construction supports its own weight only it is more susceptible to wind load than if it were supporting the roof load. The aim of the tests reported in this paper was to determine whether a traditional brick-block

cavity gable wall that was connected to the roof by the minimum strap connections required under the Building Regulations was stable when subjected to localised wind suction.

2. ROOF CONSTRUCTION

The roof structure consisted of ten timber trussed rafters, diagonally braced, supporting clay interlocking pantiles. The rafter pitch is $27\frac{1}{2}^{o}$ and after consulting the manufacturer and also doing calculations in accordance with BS 5534[4] the tiles were fixed by nailing in each alternate course and also at the eaves and verges. Schedule 7 of The Building Regulations requires that the cavity gable wall be connected to the roof by mild steel straps of minimum cross section 30mm x 5mm at intervals not exceeding 2m. The straps used were 900mm in overall length and span over the top of the two trussed rafters nearest to the gable wall and also the inner leaf, 100mm of the strap turns down into the cavity and bears against the outside of the concrete blockwork inner leaf. Straps were also required by the Schedule to be placed at ceiling level.

There are a number of alternative details for the verge line which are used in the U.K. but the one tested was in accordance with the minimum requirements. Some of the various gable ladder designs may provide improved restraint conditions.

3. TEST ARRANGEMENT

A large triangular suction box was made and positioned approximately 75mm from the face of the top of the gable wall. The box is made from wood and was supported rigidly by a steel frame which was bolted to supporting columns. Polythene was used to form an airtight seal between the box and the wall. A fan was connected via trunking to the suction box. A test with the box supported close to the laboratory floor indicated that a suction pressure of the order of 3.5 kN/m^2 could be achieved over the area of box. Pressure tappings were made at various positions over the suction box and connected to a series of manometers so that the distribution of suction pressure over the face of the brickwork could be recorded. In all cases the variation in pressure with position proved to be negligible.

Transducers were placed in contact with the inner leaf of the gable wall and, through small holes, with the inner face of the outer leaf. Also transducers were placed at a number of positions on the two trussed rafters nearest to the gable wall.

The location of the instrumentation is shown in Figure 2.

4. RESULTS AND OBSERVATIONS

A preliminary low load test was carried out in order to ensure that the instrumentation was effectively positioned and as a result some changes were made. In this no cracking was caused. The deflection of the outer leaf increased from the base to the apex of the triangle and at a suction load of 0.6 kN/m^2 the maximum deflection was 13 mm. The two leaves of the cavity wall deflected, at the same position, by similar amounts. The trussed rafters deflected by considerably less than the wall along the verges but by a similar amount in the central area. The rafters have little out of plane stiffness and the only restraint to the central timbers are isolated bracing members. The restraint anchors at ceiling level provided a positive connection but as the bottom tie of the trussed rafters has little out of plane stiffness this member deflected with the wall.

In the second test improvements in the location of the instrumentation enabled a better assessment of the performance of the straps at the verge line. Clearly there was some relative movement between the inner leaf and the rafters and this was probably due to the restraint strap lifting and the turn-down bending which enabled the wall to deflect (see Figure 3).

Prior to the third test a plasterboard ceiling was fixed. The effect at ceiling level was considerable, at the maximum suction pressure, 0.5 kN/m^2, the deflection of the bottom element of the trussed rafter was reduced from 3.5mm to 0.4mm. The additional horizontal stiffness at this level appeared to increase the resistance to lateral movement higher up the rafters where, on average, the lateral displacement was reduced by about 25%. The effect of this stiffening of the roof structure on the displacement of the wall was relatively small but there was some decrease in its vertical curvature.

The fourth loading test was taken to failure, which occurred at a lateral suction pressure of 1.0 kN/m^2 when the wall tilted about the base of the triangle until the outer leaf had deflected the 75mm required before it touched the suction box. The inner leaf was allowed to move as the restraint straps rose and the ninety degree angle of the strap opened up, at one position the aerated concrete of the inner leaf was broken locally. Figure 4 shows how the deflection of the top of the wall and that of the top of the nearest trussed rafter increased with suction pressure. Clearly throughout the test the relative movement between wall and rafter has increased, but once the pressure exceeded 0.8 kN/m^2 the increase was dramatic until at 1.0 kN/m^2 no further load could be supported. On release of the load much of the deflection was recovered.

The top of the gable wall was demolished and rebuilt using materials from the same batch as those used for the original building. In this instance the number of restraint straps was not altered but a revised detail suggested in a Defect Action Sheet[5] was used. The detail is shown

in Figure 5. The relatively simple step of fixing the strap beneath the rafters and hence there being a cut block above rafter than below the strap is effective. The wall was restrained by the roof and at a suction pressure of 1.0 kN/m^2, the failure load in the previous test there was a relative movement between the inner leaf and the nearest rafter of 1.7mm only. The failure occurred when the concrete blocks at the strap positions failed by cracking and crushing as shown in Figure 6. The suction pressure at failure was 1.58 kN/m^2, an increase of 58% which represents an increase in failure wind speed of 26%.

A preliminary assessment of the results based on CP.3[6] indicates that the design wind speeds corresponding to 1 kN/m^2 and 1.58 kN/m^2 are 45 m/s and 57 m/s. This simple assessment indicates that the improved detail would mean that the minimum recommended frequency of strapping could be used with a margin of safety throughout the whole of the U.K. However failures are often wholly localised and this simple interpretation in terms of exposure to wind is unlikely to be wholly realistic.

5. CONCLUSIONS

The failure pressure for the top triangle of a gable wall, supported by restraint straps in accordance with Schedule 7 to the Building Regulations placed over the rafters is 1.0 kN/m^2. The full interpretation of this in terms of real wind speeds will be highly complex and remains to be done.

However it is clear that with the traditional detail the ceiling is very effective in stiffening the roof framework and in making the ceiling straps work effectively. Also the revised detail for strapping at the verges, as suggested by the Building Research Station is an effective way of improving the restraint.

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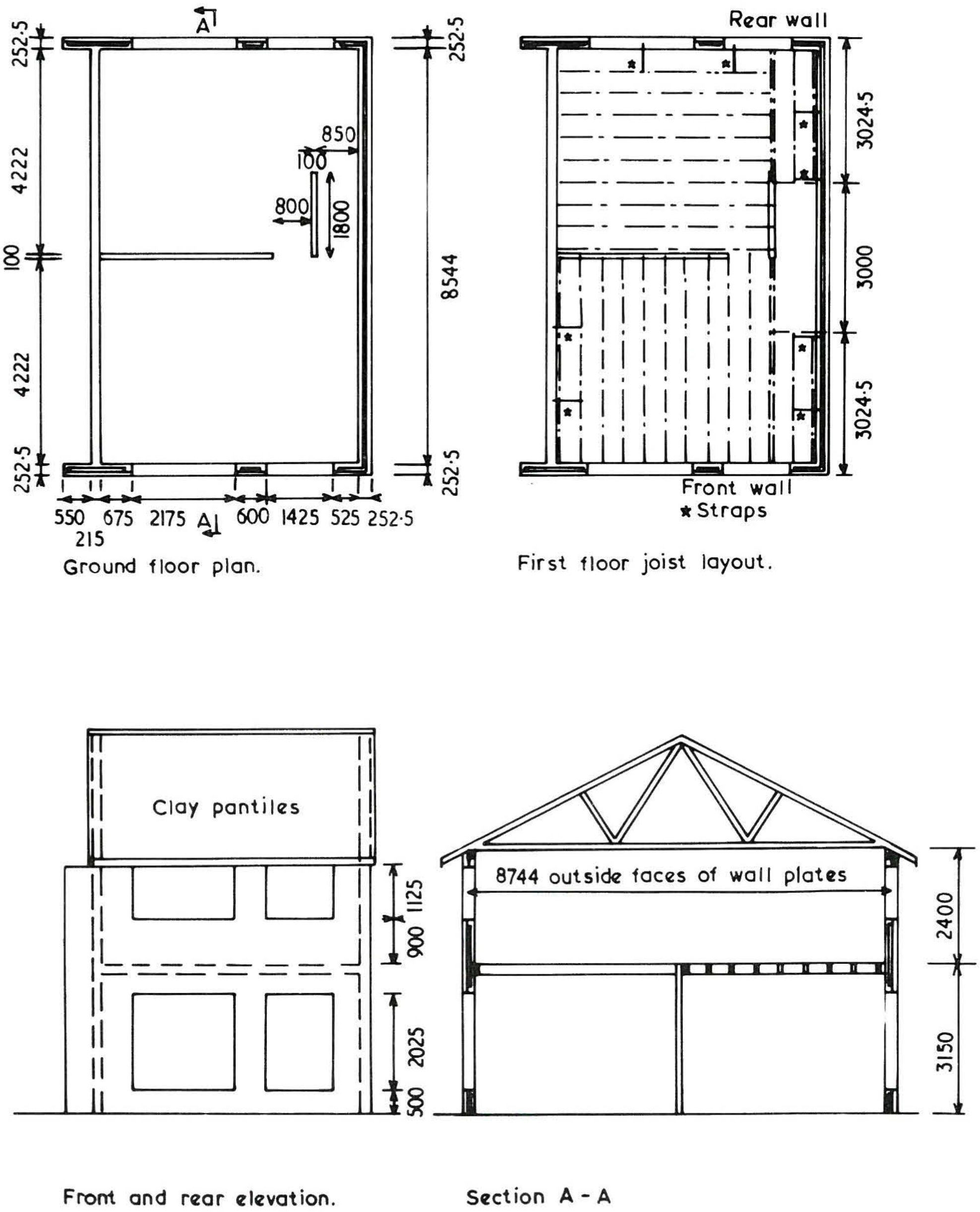


FIGURE 1: Elevation and Plan of House

FIGURE 2: Position of Displacement Transducers

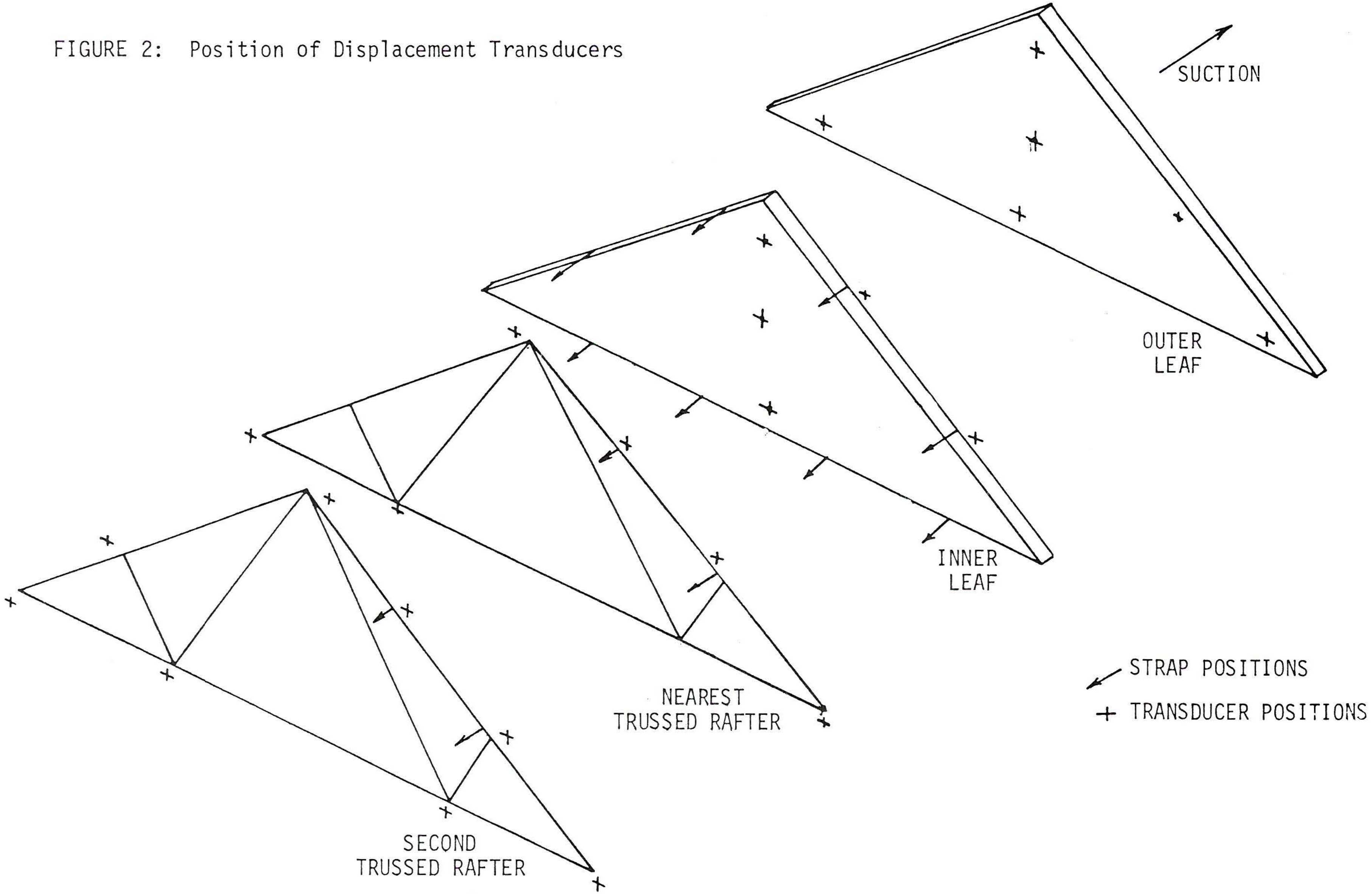


FIGURE 3: Strap Detail Before and During Loading

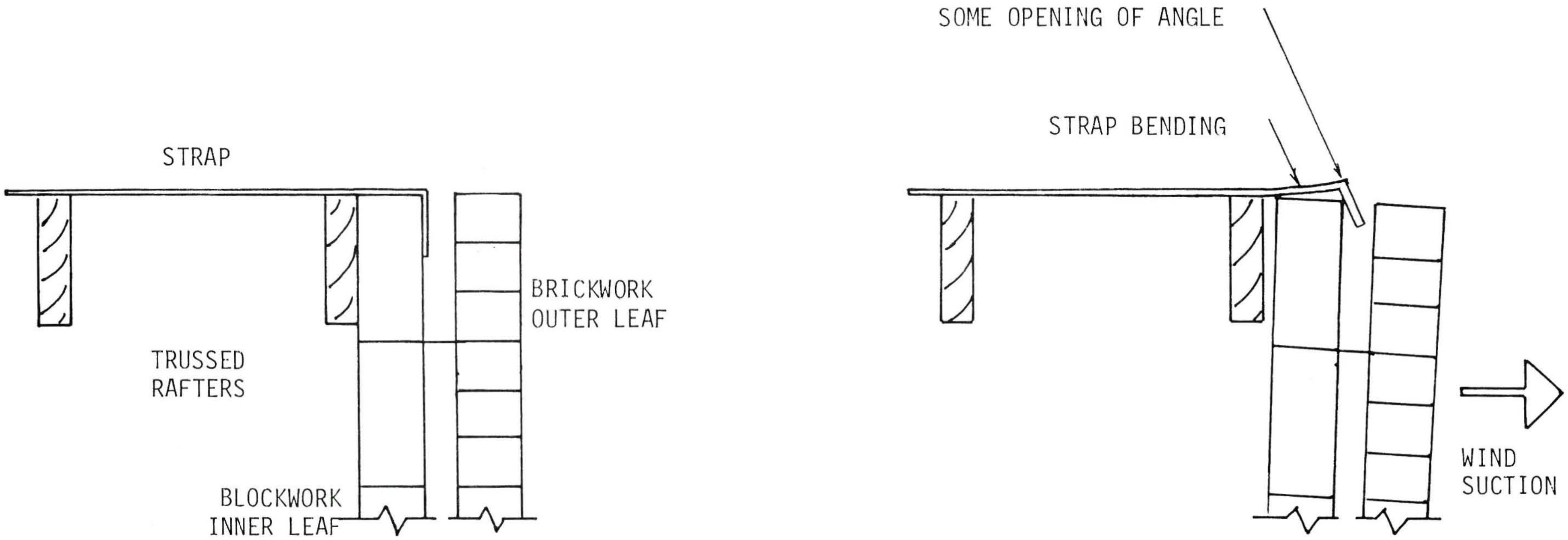
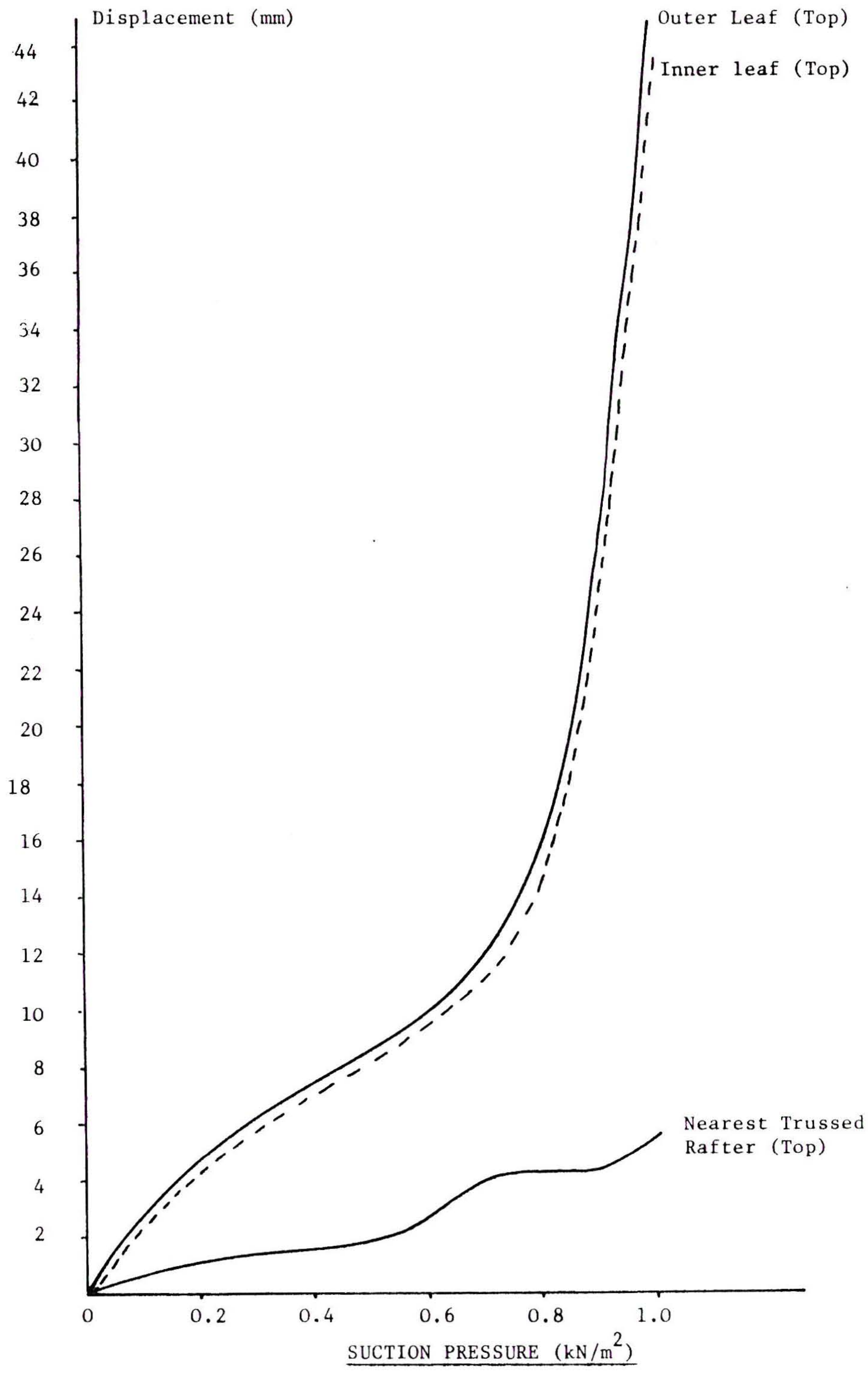


FIGURE 4. GRAPH TO SHOW THE VARIATION OF THE DISPLACEMENT AT THE TOP OF THE WALL AND TRUSSED RAFTER WITH SUCTION PRESSURE



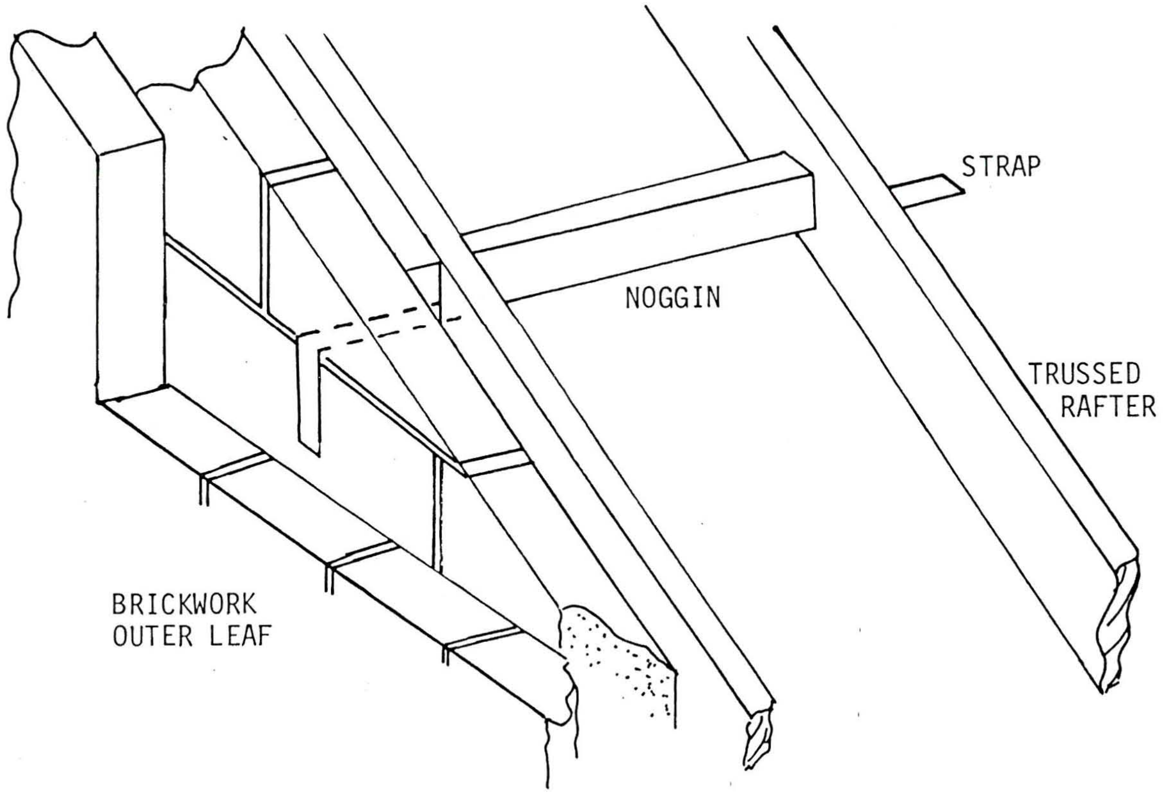
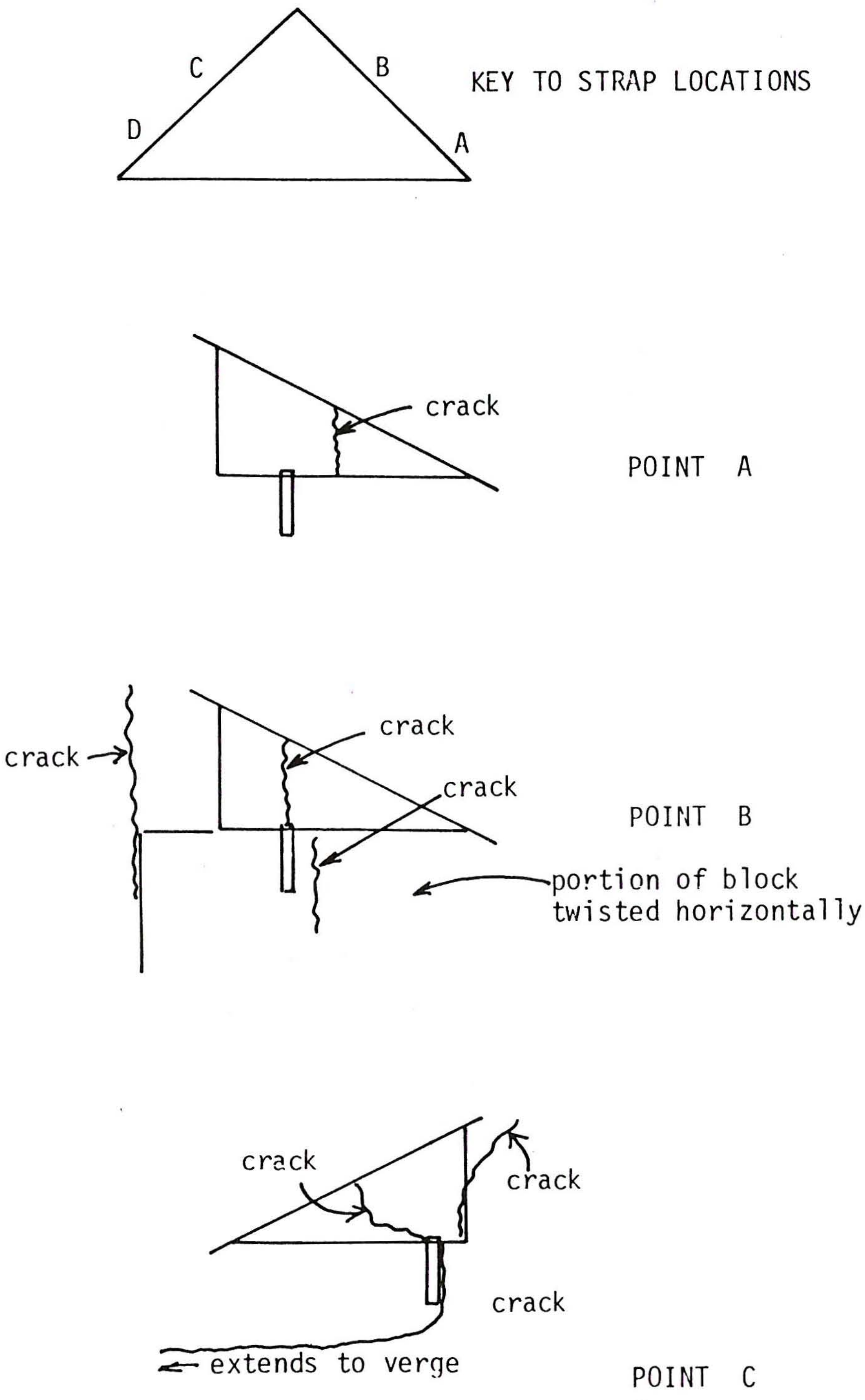


FIGURE 5: Improved Strap Detail

FIGURE 6: Crack Details



POINT D: Cut block over strap loosened when shook. No previous sign of cracking